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ELEMENTS

OF

NATURAL

PHILOSOPHY.

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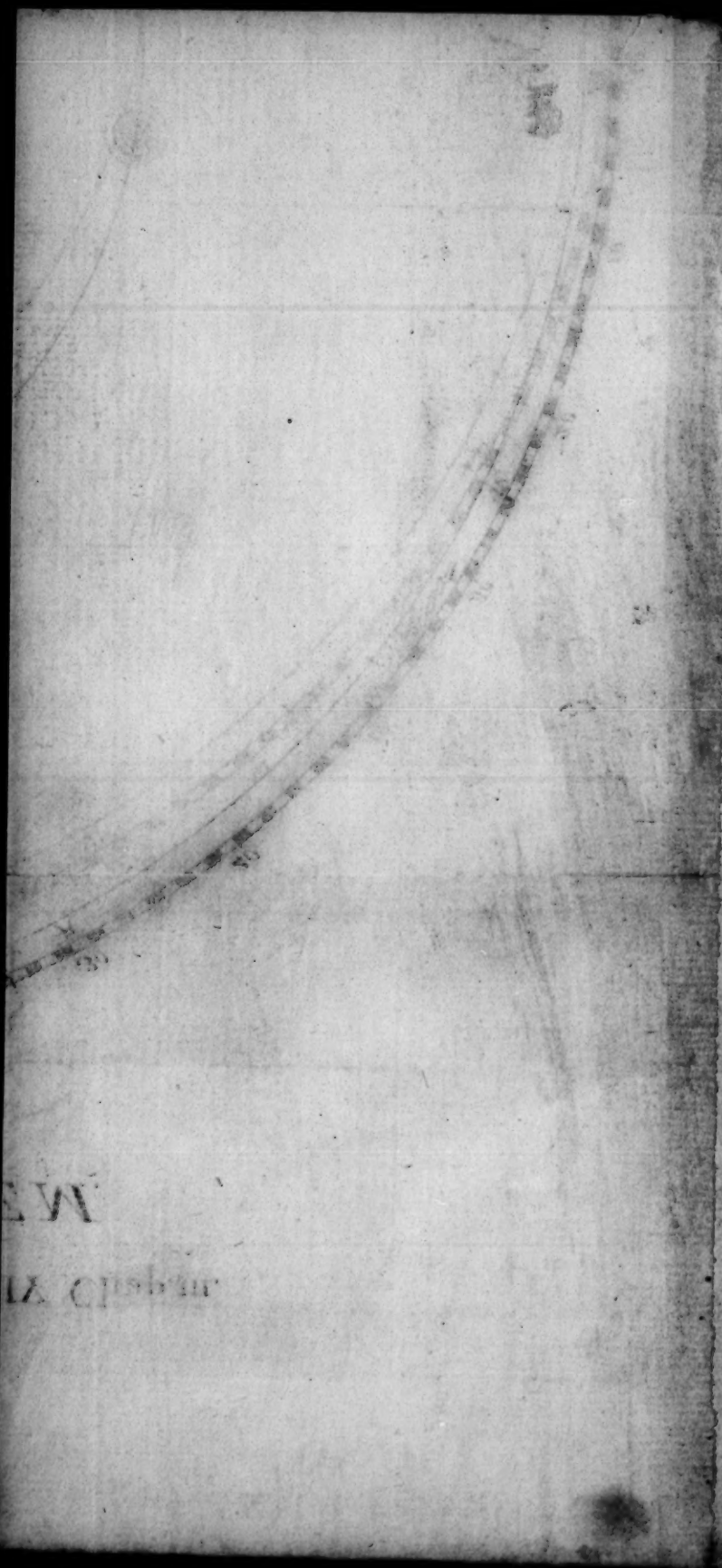
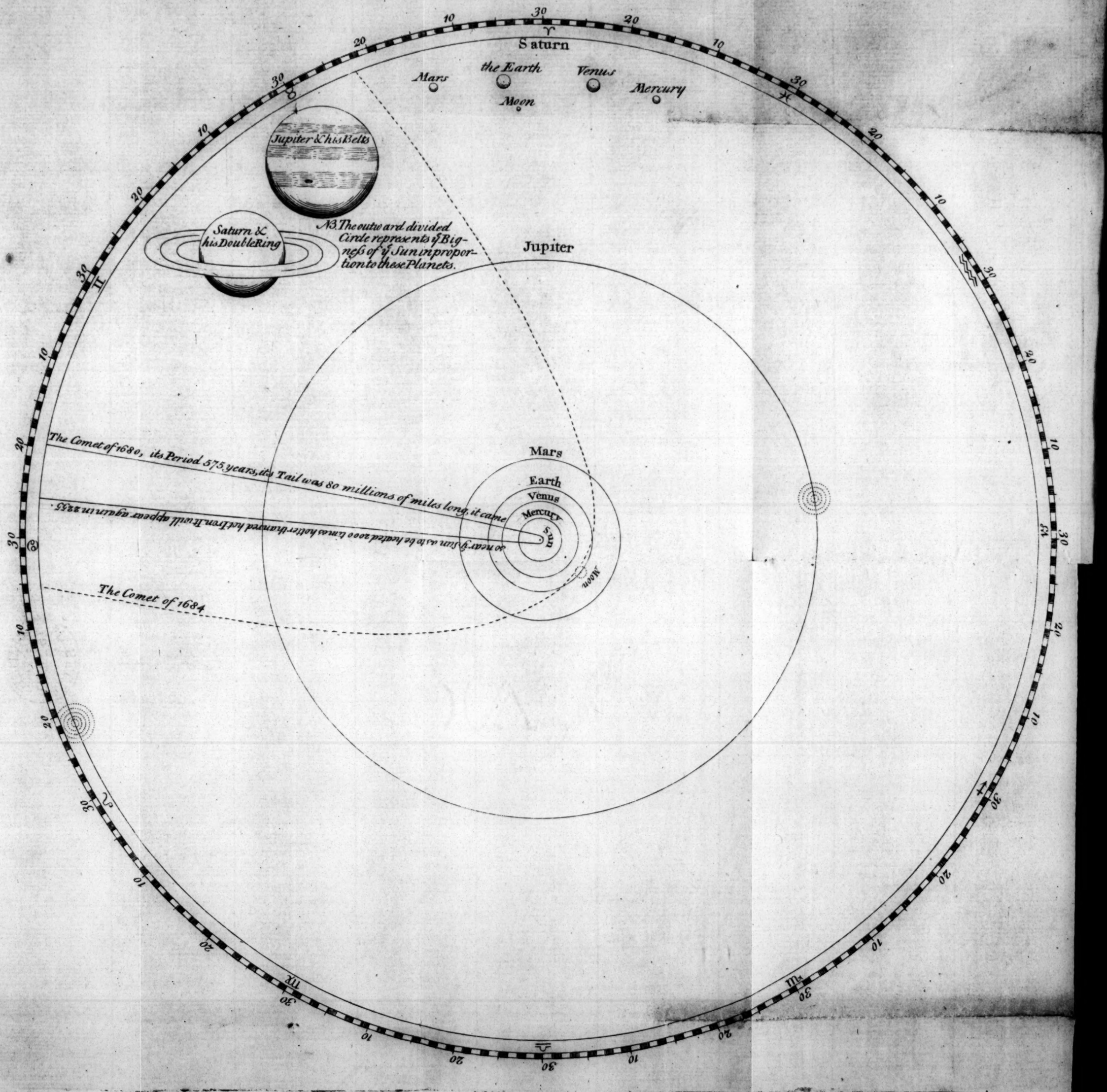


THE COPERNICAN SYSTEM.



ELEMENTS

OF

NATURAL

PHILOSOPHY.

BY

JOHN LOCKE, Esq;

GLASGOW:

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BRITISH MUSEUM

ADVERTISEMENT.

THESE Elements of natural Philoſophy, Mr. Locke had compoſed, or rather dictated, for the uſe of a young gentleman, whoſe education he had very much at heart. They are an abſtract or ſummary of whatever is moſt material in natural philoſophy; which Mr. Locke did afterwards explain more at large to that young gentleman. The ſame is practiſed in the univerſities, where it is cuſtomary for the profeſſors to dictate ſuch abrigements, to ſerve for the ſub-

ject and rule of their lectures. And therefore this ſmall tract is far from being what Mr. Locke would have made it, had he written upon that matter profeſſedly, and deſigned to make it a complete work.

AFTER all, I may take upon me to ſay, that, in its kind, this piece is no way to be deſpiſed. We wanted ſuch a work in Engliſh: and it would not have been an eaſy matter to find any other perſon who could have comprehended ſo many things in ſo few words, and in ſo clear and diſtinct a manner. Great uſe may be made of it in the in-

ſtruction of young gentlemen, as it was originally deſigned by Mr. Locke. And perſons even of riper years may improve by it; either by recalling ideas that had ſlipt out of their memory; or by informing themſelves of ſeveral things, which were unknown to them.

MAIZEAUX.

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ELEMENTS OF NATURAL PHILOSOPHY.

CHAP. I.

OF MATTER AND MOTION.

MATTER is an extended ſolid ſubſtance; which, being comprehended under diſtinct ſurfaces, makes ſo many particular diſtinct bodies.

MOTION is ſo well known by the ſight and touch, that to

uſe words to give a clearer idea of it, would be in vain.

MATTER, or body, is indifferent to motion, or reſt.

THERE is as much force required to put a body, which is in motion, at reſt; as there is to ſet a body, which is at reſt, into motion.

NO parcel of matter can give it ſelf either motion or reſt; and therefore a body at reſt will remain ſo eternally, except ſome external cauſe puts it in motion; and a body in motion will move

eternally, unleſs ſome external cauſe ſtops it.

A BODY in motion will always move on in a ſtrait line, unleſs it be turned out of it by ſome external cauſe; becauſe a body can no more alter the determination of its motion, than it can begin it, alter or ſtop its motion itſelf.

THE ſwiftneſs of motion is meaſured by diſtance of place, and length of time wherein it is performed. For inſtance, if A and B, bodies of equal or different bigneſs, move each of them

an inch in the ſame time; their motions are equally ſwift: but if A moves two inches, in the time whilſt B is moving one inch; the motion of A is twice as ſwift as that of B.

THE quantity of motion is meaſured by the ſwiftneſs of the motion, and the quantity of the matter moved, taken together. For inſtance, if A, a body equal to B, moves as ſwift as B; then it hath an equal quantity of motion. If A hath twice as much matter as B, and moves equally as ſwift; it hath double the quan-

tity of motion; and ſo in proportion.

IT appears, as far as human obſervation reaches, to be a ſettled law of nature, that "all bo-"dies have a tendency, attracti-"on, or gravitation towards one "another."

THE ſame force, applied to two different bodies, produces always the ſame quantity of motion in each of them. For inſtance, let a boat, which, with its loading, is one tun, be tied at a diſtance to another veſſel, which, with its lading, is twenty-ſix tuns; if the

rope that ties them together be pulled, either in the leſs or bigger of theſe veſſels, the leſs of the two, in their approach one to another, will move twenty-ſix foot, while the other moves but one foot.

WHEREFORE the quantity of matter in the earth being twenty-ſix times more, than in the moon; the motion in the moon towards the earth, by the common force of attraction, by which they are impelled towards one another, will be twenty-ſix times as faſt as in the earth; that is, the moon will move twenty-ſix miles to-

wards the earth, for every mile the earth moves towards the moon.

HENCE it is, that in this natural tendency of bodies towards one another, that in the leſſer is conſidered as gravitation; and that in the bigger as attraction: becauſe the motion of the leſſer body, by reaſon of its much greater ſwiftneſs, is alone taken notice of.

THIS attraction is the ſtrongeſt, the nearer the attracting bodies are to each other; and in different diſtances of the ſame bodies, is reciprocally in the du-

plicate proportion of thoſe diſtances. For inſtance, if two bodies, at a given diſtance, attract each other with a certain force, at half the diſtance, they will attract each other with four times that force; at one third of the diſtance, with nine times that force; and ſo on.

Two bodies, at a diſtance, will put one another into motion by the force of attraction; which is unexplicable by us, tho' made evident to us by experience, and ſo to be taken as a principle in natural philoſophy.

SUPPOSING then the earth the ſole body in the univerſe, and at reſt; if God ſhould create the moon, at the ſame diſtance that it is now from the earth; the earth and the moon would preſently begin to move one towards another in a ſtrait line by this motion of attraction or gravitation.

IF a body, that by the attraction of another would move in a ſtrait line towards it, receives a new motion any ways oblique to the firſt; it will no longer move in a ſtrait line, according to either of thoſe directions; but in a curve, that will partake of both:

and this curve will differ, according to the nature and quantity of the forces that concurred to produce it: as, for inſtance, in many caſes it will be ſuch a curve as ends where it begun, or recurs into it ſelf; that is, makes up a circle, or an elipſis or oval very little differing from a circle.

CHAP. II.

OF THE UNIVERSE.

TO any one, who looks about him in the world, there are obvious ſeveral diſtinct maſſes of matter, ſeparate from one another; ſome whereof have diſcernable motions. Theſe are the ſun, the fixt ſtars, the comets, and the planets; amongſt which, this earth, which we inhabit, is one. All theſe are viſible to our naked eyes.

BESIDES theſe, teleſcopes

have diſcovered ſeveral fixt ſtars, inviſible to the naked eye; and ſeveral other bodies moving about ſome of the planets; all which were inviſible and unknown, before the uſe of proſpective glaſſes were found.

THE vaſt diſtances between theſe great bodies are called intermundane ſpaces; in which though there may be ſome fluid matter, yet it is ſo thin and ſubtile; and there is ſo little of that in reſpect of the great maſſes that move in thoſe ſpaces, that it is as much as nothing.

THESE maſſes of matter are, either luminous, or opaque, or dark.

LUMINOUS bodies, are ſuch as give light of themſelves; and ſuch are the ſun, and the fixt ſtars.

DARK or opaque bodies, are ſuch as emit no light of themſelves, though they are capable of reflecting of it, when it is caſt upon them from other bodies; and ſuch are the planets.

THERE are ſome opaque bodies, as, for inſtance, the comets, which, beſides the light that they

may have from the ſun, ſeem to ſhine with a light that is nothing elſe but an accenſion, which they receive from the ſun, in their near approaches to it, in their reſpective revolutions.

THE fixt ſtars are called fixt, becauſe they always keep the ſame diſtance one from another.

THE ſun, at the ſame diſtance from us that the fixt ſtars are, would have the appearance of one of the fixt ſtars.

CHAP. III.

OF OUR SOLAR SYSTEM.

OUR ſolar ſyſtem conſiſts of the ſun; and the planets and comets, moving about it.

THE planets are bodies, which appear to us like ſtars; not that they are luminous bodies, that is, have light in themſelves; but they ſhine by reflecting the light of the ſun.

THEY are called planets from a Greek word, which ſignifies

wandering; becauſe they change their places, and do not always keep the ſame diſtance with one another, nor with the fixt ſtars, as the fixt ſtars do.

THE planets are either primary, or ſecondary.

THERE are ſix primary planets, *viz.* Mercury, Venus, the Earth, Mars, Jupiter, and Saturn.

ALL theſe move round the ſun, which is, as it were, the center of their motions.

THE ſecondary planets move

round about other planets. Beſides the moon, which moves about the earth; four moons move about Jupiter, and five about Saturn, which are called their ſatellites.

THE middle diſtances of the primary planets from the ſun, are as follow:

Mercury	is diſtant	32,000,000	ſtatute miles
Venus	from the	59,000,000	each 528
The Earth	Sun's	81,000,000	Engliſh,
Mars	center	123,000,000	and 4943
Jupiter	about	424,000,000	French feet.
Saturn		777,000,000	

THE orbits of the planets, and their reſpective diſtances from the ſun, and from one another, to-

gether with the orbit of a comet, may be ſeen in the figure of the ſolar ſyſtem hereunto annexed.

THE periodical times of each planet's revolution about the ſun, are as follow:

		Y.	D.	H.	M.
Mercury	Revolves about the Sun in the ſpace of	0	88	0	0
Venus		0	225	0	0
The Earth		0	365	5	49
Mars		1	322	0	●
Jupiter		11	319	0	0
Saturn		29	138	0	●

THE planets move round about the ſun from weſt to eaſt in the zodiac: or, to ſpeak plainer, are always found amongſt ſome of

the ſtars of thoſe conſtellations, which make the twelve ſigns of the zodiac.

THE motion of the planets about the ſun, is not perfectly circular, but rather elliptical.

THE reaſon of their motions in curve lines, is the attraction of the ſun, or their gravitations towards the ſun, (call it which you pleaſe); and an oblique or ſidelong impulſe or motion.

THESE two motions or tendencies, the one always endeavouring to carry them in a ſtrait line

from the circle they move in, and the other endeavouring to draw them in a ſtrait line to the ſun, make that curve line they revolve in.

THE motion of the comets about the ſun, is in a very long ſlender oval: whereof one of the focuſes is the center of the ſun, and the other very much beyond the ſphere of Saturn.

THE moon moves about the earth, as the earth doth about the ſun. So that it hath the center of its motion in the earth; as the earth hath the center of its revo-

lution in the ſun, about which it moves.

THE moon makes its ſynodical motion about the earth, in twenty nine days, twelve hours, and about forty four minutes.

IT is full moon, when the earth being between the ſun and the moon, we ſee all the enlightened part of the moon: new moon, when the moon being between us and the ſun, its enlightened part is turned from us: and half moon, when the moon being in the quadratures, as the aſ-

tronomers call it, we ſee but half the enlightened part.

AN eclipſe of the moon is, when the earth, being between the ſun and the moon, hinders the light of the ſun from falling upon and being reflected by the moon. If the light of the ſun is kept off from the whole body of the moon, it is a total eclipſe; if from a part only, it is a partial one.

AN eclipſe of the ſun is, when the moon, being between the ſun and the earth, hinders the light of the ſun from coming to us. If

the moon hides from us the whole body of the ſun, it is a total eclipſe; if not, a partial one.

OUR ſolar ſyſtem is diſtant from the fixt ſtars 20,000,000,000 ſemi-diameters of the earth: or, as Mr. Huygens expreſſes this diſtance, in his coſmotheoros(1); the fixt ſtars are ſo remote from the earth, that, if a cannon bullet ſhould come from one of the fixt ſtars with as ſwift a motion as it hath when it is ſhot out of the

(1) Chriſtiani Hugenii ΚΟΣΜΟΘΕΩΡΟΣ, ſive de terris cœleſtibus earumque ornatu, conjecturæ &c. p. m. 137.

mouth of a cannon; it would be 700,000 years in coming to the earth.

THIS vaſt diſtance ſo much abates the attraction of thoſe remote bodies, that its operation upon thoſe of our ſyſtem is not at all ſenſible, nor would draw away or hinder the return of any of our ſolar comets; tho' ſome of them ſhould go ſo far from the ſun, as not to make the revolution about it in leſs than a thouſand years.

IT is more ſuitable to the wiſdom, power and greatneſs of God, to think that the fixt ſtars

are all of them ſuns, with ſyſtems of inhabitable planets moving about them, to whoſe inhabitants he diſplays the marks of his goodneſs as well as to us; rather than to imagine that thoſe very remote bodies, ſo little uſeful to us, were made only for our ſake.

CHAP. IV.

OF THE EARTH, CONSIDERED AS A PLANET.

THE earth, by its revolution about the ſun in three hundred and ſixty five days, five hours, forty nine minutes, makes that ſpace of time we call a year.

THE line, which the center of the earth deſcribes in its annual revolution about the ſun, is called the ecliptic.

THE annual motion of the

earth about the ſun, is in the order of the ſigns of the zodiac; that is, ſpeaking vulgarly, from weſt to eaſt.

BESIDES this annual revolution of the earth about the ſun, in the ecliptic; the earth turns round upon its own axis in twenty-four hours.

THE turning of the earth upon its own axis every twenty-four hours, whilſt it moves round the ſun in a year, we may conceive by the running of a bowl on a bowling-green; in which not only the center of the bowl hath

a progreſſive motion on the green; but the bowl in its going forward, from one part of the green to another, turns round about its own axis.

THE turning of the earth on its own axis, makes the difference of day and night; it being day in thoſe parts of the earth, which are turned towards the ſun; and night, in thoſe parts which are in the ſhade, or turned from the ſun.

THE annual revolution of the earth in the ecliptic, is the cauſe of the different ſeaſons, and of

the ſeveral lengths of days and nights, in every part of the world, in the courſe of the year.

THE reaſon of it is the earth's going round its own axis in the ecliptic, but at the ſame time keeping every where its axis equally inclined to the plane of the ecliptic, and parallel to it ſelf. For the plane of the ecliptic, inclining to the plane of the equator twenty three degrees and an half, makes that the earth, moving round in the ecliptic, hath ſometimes one of its poles, and ſometimes the other nearer the ſun.

If the diameter of the ſun be to the diameter of the earth, as 48 to 1, as by ſome it is accounted; then the diſk of the ſun, ſpeaking, *numero rotundo*, is above two thouſand times bigger than the diſk of the earth; and the globe of the ſun above a hundred thouſand times bigger than the globe of the earth.

The diſtance of the earth's orbit from the ſun, is above twenty thouſand ſemi-diameters of the earth.

If a cannon bullet ſhould come

from the ſun, with the ſame velocity it hath, when it is ſhot out of the mouth of a cannon, it would be twenty five years in coming to the earth.

CHAP. V.

OF THE AIR AND ATMOSPHERE.

WE have already conſidered the earth as a planet, or one of the great maſſes of matter moving about the ſun; we ſhall now conſider it as it is made up of its ſeveral parts, abſtracting from its diurnal and annual motions.

THE exterior part of this our habitable world is the air or atmoſphere; a light, thin, fluid, or

ſpringy body, that incompaſſes the ſolid earth on all ſides.

THE height of the atmoſphere above the ſurface of the ſolid earth, is not certainly known; but that it doth reach to but a very ſmall part of the diſtance betwixt the earth and the moon, may be concluded from the refraction of the rays coming from the ſun, moon, and other luminous bodies.

THOUGH conſidering that the air we are in, being near a thouſand times lighter than water; and that the higher it is, the leſs it is compreſſed by the ſuperior

incumbent air, and ſo conſequently being a ſpringy body, the thinner it is; and conſidering alſo that a pillar of air of any diameter is equal in weight to a pillar of quickſilver of the ſame diameter of between twenty-nine and thirty inches height; we may infer that the top of the atmoſphere is not very near the ſurface of the ſolid earth.

It may be concluded, that the utmoſt extent of the atmoſphere reaches upwards from the ſurface of the ſolid earth that we walk on, to a good diſtance above us; firſt, if we conſider that a column of

air of any given diameter is equiponderant to a column of quickſilver of between twenty-nine and thirty inches height. Now quickſilver being near fourteen times heavier than water, if air was as heavy as water, the atmoſphere would be about fourteen times higher than the column of quickſilver, *i. e.* about thirty four foot.

SECONDLY, if we conſider, that air is a thouſand times lighter than water, then a pillar of air equal in weight to a pillar of quickſilver of thirty inches high will be 6800 foot; whereby we come to know that the air or at-

moſphere is 6800, *i. e.* near ſeven miles high.

THIRDLY, if we conſider that the air is a ſpringy body, and that That which is neareſt the earth is compreſſed by the weight of all the atmoſphere that is above it, and reſts perpendicularly upon it; we ſhall find that the air here, near the ſurface of the earth, is much denſer and thicker than it is in the upper parts. For example, if upon a fleece of wool you lay another, the under one will be a little compreſſed by the weight of that which lies upon it; and ſo both of them by a

third, and ſo on; ſo that if ten thouſand were piled one upon another, the under-one would, by the weight of all the reſt, be very much compreſſed, and all the parts of it be brought abundantly cloſer together, than when there was no other upon it; and the next to that a little leſs compreſſed, the third a little leſs than the ſecond, and ſo on till it came to the uppermoſt, which would be in its full expanſion, and not compreſſed at all. Juſt ſo it is in the air; the higher you go in it, the leſs it is compreſſed, and conſequently the leſs denſe it is; and ſo the upper part being exceed-

ingly thiner than the lower part, which we breathe in; (which is that that is a thouſand times lighter than water); the top of the atmoſphere is probably much higher than the diſtance above aſſigned.

THAT the air near the ſurface of the earth will mightily expand itſelf when the preſſure of the incumbent atmoſphere is taken off, may be abundantly ſeen in the experiments made by Mr. Boyle in his pneumatic engine. In his phyſico-mechanical experiments concerning the air, he de-

clares (1) it probable that the atmoſphere may be ſeveral hundred miles high; which is eaſy to be admitted, when we conſider what he proves in another part of the ſame treatiſe, *viz.* that the air here about the ſurface of the earth, when the preſſure is taken from it, will dilate itſelf above a hundred and fifty-two times.

THE atmoſphere is the ſcene

(1) New experiments phyſico-mechanical, touching the ſpring of the air, and its effects; (made for the moſt part in a new pneumatical engine) written by the honourable ROBERT BOYLE, Eſq; Experiment xxxvi. p. 155. Oxford, 1662, in 4to.

of the meteors; and therein is collected the matter of rain, hail, ſnow, thunder, and lightning; and a great many other things obſervable in the air.

CHAP. VI.

OF METEORS IN GENERAL.

BESIDES the ſpringy particles of pure air, the atmoſphere is made up of ſeveral ſteams or minute particles of ſeveral ſorts, riſing from the earth and the waters, and floating in the air, which is a fluid body, and, though much finer and thiner, may be conſidered in reſpect of its fluidity to be like water, and ſo capable, like other liquors, of having heterogeneous particles floating in it.

THE moſt remarkable of them are, firſt, the particles of water raiſed into the atmoſphere, chiefly by the heat of the ſun, out of the ſea and other waters, and the ſurface of the earth; from whence it falls in dew, rain, hail and ſnow.

OUT of the vapours riſing from moiſture, the clouds are principally made.

CLOUDS do not conſiſt wholly of watery parts; for beſides the aqueous vapours that are raiſed into the air, there are alſo ſul-

phureous and ſaline particles, that are raiſed up, and in the clouds mixed with the aqeuous particles, the effects whereof are ſometimes very ſenſible; as particulary in lightning, and thunder, when the ſulphureous and nitrous particles firing, break out with that violence of light and noiſe, which is obſervable in thunder, and very much reſembles gun-powder.

THAT there are nitrous particles raiſed into the air, is evident from the nouriſhment which rain gives to vegetables more than any other water; and alſo by the collection of niter or ſalt-peter in

heaps of earth, out of which it has been extracted, if they beexpoſed to the air, ſo as to be kept from rain; not to mention other efforts wherein the nitrous ſpirit in the air ſhews it ſelf.

CLOUDS are the greateſt and moſt conſiderable of all the meteors, as furniſhing matter and plenty to the earth. They conſiſt of very ſmall drops of water; and are elevated a good diſtance above the ſurface of the earth; for a cloud is nothing but a miſt flying high in the air, as a miſt is nothing but a cloud here below.

How vapours are raiſed into the air in inviſible ſteams by the heat of the ſun out of the ſea, and moiſt parts of the earth, is eaſily underſtood; and there is a viſible inſtance of it in ordinary diſtillations. But how theſe ſteams are collected into drops, which bring back the water again, is not ſo eaſy to determine.

To thoſe, who will carefully obſerve, perhaps it will appear probable, that it is by that, which the chymiſts call precipitation; to which it anſwers in all its parts.

THE air may be looked on as a clear and pellucid menſtruum, in which the inſenſible particles of diſſolved matter float up and down, without being diſcerned, or troubling the pellucidity of the air; when on a ſudden, as if it were by a precipitation, they gather into the very ſmall, but viſible miſty drops that make clouds.

THIS may be obſerved ſometimes in a very clear ſky; when, there not appearing any cloud, or any thing opaque, in the whole horizon, one may ſee on a ſud-

den clouds gather, and all the hemiſphere overcaſt; which cannot be from the riſing of new aqueous vapours at that time; but from the precipitation of the moiſture that inviſible particles floated in the air, into very ſmall, but very viſible drops, which by a like cauſe being united into greater drops, they become too heavy to be ſuſtained in the air; and ſo fall down in rain.

HAIL ſeems to be the drops of rain frozen in their falling.

SNOW is the ſmall particles of

water frozen before they unite into drops.

THE regular figures, which branch out in flakes of ſnow, ſeem to ſhew that there are ſome particles of ſalt mixed with the water, which makes them unite in certain angles.

THE rain-bow is reckoned one of the moſt remarkable meteors, though really it be no meteor at all; but the reflection of the ſun-beams from the ſmalleſt drops of a cloud or miſt, which are placed in a certain angle made by the concurrence of two lines, the one

drawn from the ſun, and the other from the eye to theſe little drops in the cloud, which reflect the ſun-beams; ſo that two people looking upon a rain-bow at the ſame time, do not ſee exactly the ſame rain-bow.

CHAP. VII.

OF SPRINGS, RIVERS, AND THE SEA.

PART of the water, that falls down from the clouds, runs away upon the ſurface of the earth into channels, which convey it to the ſea; and part of it is imbibed in the ſpungy ſhell of the earth, from whence ſinking lower by degrees, it falls down into ſubterranean channels, and ſo under ground paſſes into the ſea; or elſe meeting with beds of rock or clay, it is hindered from ſinking lower,

and ſo breaks out in ſprings, which are moſt commonly in the ſides, or at the bottom of hilly ground.

SPRINGS make little rivulets; thoſe uniting make brooks; and thoſe coming together make rivers, which empty themſelves into the ſea.

THE ſea is a great collection of waters in the deep valleys of the earth. If the earth were all plain, and had not thoſe deep hollows, the earth would be all cover'd with water; becauſe the water, being lighter than the

earth, would be above the earth, as the air is above the water.

THE moſt remarkable thing in the ſea, is that motion of the water called tides. It is a riſing and falling of the water of the ſea. The cauſe of this is the attraction of the moon, whereby the part of the water in the great ocean which is neareſt the moon, being moſt ſtrongly attracted, is raiſed higher than the reſt; and the part oppoſite to it, on the contrary ſide, being leaſt attraced, is alſo higher than the reſt. And theſe two oppoſite riſes of the ſurface of the water in the

great ocean, following the motion of the moon from eaſt to weſt, and ſtriking againſt the large coaſts of the continents that lie in its way; from thence rebounds back again, and ſo makes floods and ebbs in narrow ſeas, and rivers remote from the great ocean. Herein we alſo ſee the reaſon of the times of the tides, and why they ſo conſtantly follow the courſe of the moon.

CHAP. VIII.

OF SEVERAL SORTS OF EARTH, STONES, METALS, MINERALS, AND OTHER FOSSILS.

THIS ſolid globe we live upon is called the earth, tho' it contains in it a great variety of bodies, ſeveral whereof are not properly earth; which word, taken in a more limited ſenſe, ſignifies ſuch parts of this globe, as are capable, being expoſed to the air, to give rooting and nouriſhment to plants, ſo that they may ſtand and grow in it. With ſuch

earth as this, the greateſt part of the ſurface of this globe is covered; and it is, as it were, the ſtore-houſe from whence all the living creatures of our world have originally their proviſions; for from thence all the plants have their ſuſtenance, and ſome few animals, and from theſe all the other animals.

OF earth, taken in this ſenſe, there are ſeveral ſorts; for inſtance, common mould, or garden-earth, clay of ſeveral kinds, ſandy ſoils.

BESIDES theſe there is medi-

cinal earth; as that which is called Terra Lemnia, Bolus Armena, and divers others.

AFTER the ſeveral earths, we may conſider the parts of the ſurface of this globe, which is barren; and ſuch, for the moſt part, are ſand, gravel, chalk, and rocks, which produce nothing, where they have no earth mixt among them. Barren ſands are of divers kinds; and conſiſt of ſeveral little irregular ſtones without any earth, and of ſuch there are great deſarts to be ſeen in ſeveral parts of the world.

BESIDES theſe, which are moſt remarkable on the ſurface of the earth, there are found deeper in this globe many other bodies, which, becauſe we diſcover by digging into the bowels of the earth, are called, by one common name, Foſſils; under which are comprehended metals, minerals or half metals, ſtones of divers kinds, and ſundry bodies that have the texture between earth and ſtone.

To begin with thoſe foſſils which come neareſt the earth; under this head we may reckon the ſeveral ſorts of oker, chalk,

that which they call black lead, and other bodies of this kind, which are harder than earth, but have not the conſiſtency and hardneſs of perfect ſtone.

NEXT to theſe may be conſidered ſtones of all ſorts; whereof there is almoſt an infinite variety. Some of the moſt remarkable, either for beauty or uſe, are theſe: marble of all kinds, porphyry, granit, free-ſtone, *etc.* flints, agats, cornelians, pebbles, under which kind come the precious ſtones, which are but pebbles of an exceſſive hardneſs, and when they are cut and poliſhed,

they have an extraordinary luſtre. The moſt noted and eſteemed are, diamonds, rubies, amethiſts, emeralds, topazes, opats.

BESIDES theſe, we muſt not omit thoſe, which, tho' of not ſo much beauty, yet are of greater uſe, viz. loadſtones, whetſtones of all kinds, limeſtones, calamint or lapis calaminaris; and abundance of others.

OVER and above, there are found in the earth ſeveral ſorts of ſalts, as eating or common ſalt, vitriol, ſalt gemma, and others.

THE minerals, or ſemi-metals, that are dug out of the bowels of the earth, are antimony, cinnabar, zink, *etc.* to which may be added brimſtone.

BUT the bodies of moſt uſe, that are ſought for out of the depths of the earth, are the metals, which are diſtinguiſhed from other bodies by their weight, fuſibility, and malleableneſs; of which there are theſe ſorts, gold, ſilver, copper, tin, lead, and the moſt valuable of them all, iron; to which one may join that ano-

mulous body, quickſilver or mercury.

HE, that deſires to be more particularly informed concerning the qualities and properties of theſe ſubterraneous bodies, may conſult natural hiſtorians and chymiſts.

WHAT lies deeper towards the center of the earth we know not, but a very little beneath the ſurface of this globe; and whatever we fetch from under ground is only what is lodged in the ſhell of the earth.

ALL ſtones, metals, and minerals, are real vegetables; that is, grow organically from proper ſeeds, as well as plants.

CHAP. IX.

OF VEGETABLES OR PLANTS.

NEXT to the earth itſelf, we may conſider thoſe that are maintained on its ſurface; which tho' they are faſtened to it, yet are very diſtinct from it: and thoſe are the whole tribe of vegetables or plants. Theſe may be divided into three ſorts, herbs, ſhrubs, and trees.

HERBS are thoſe plants, whoſe ſtalks are ſoft, and have nothing woody in them, as graſs, ſow-

thiſtle, and hemlock. Shrubs and trees have all wood in them: but with this difference, that ſhrubs grow not to the height of trees, and uſually ſpread into branches near the ſurface of the earth; whereas trees generally ſhoot up in one great ſtem or body, and then, at a good diſtance from the earth, ſpread into branches: thus, gooſeberries, and currants, are ſhrubs; oaks, and cherries, are trees.

In plants, the moſt conſiderable parts are theſe, the root, the ſtalk, the leaves, the flower, and the ſeed. There are very few of

them that have not all theſe parts, tho' ſome few there are that have no ſtalk; others that have no leaves; and others, that have no flowers; but without ſeed or root I think there are none.

IN vegetables, there are two things chiefly to be conſidered, their nouriſhment, and propagation.

THEIR nouriſhment is thus: the ſmall and tender fibres of the roots, being ſpread under ground, imbibe from the moiſt earth juice fit for their nouriſhment: this is conveyed by the ſtalk up into the

branches, and leaves, through little, and, in ſome plants, imperceptible tubes, and from thence by the bark returns again to the root: ſo that there is in vegetables, as well as in animals, a circulation of the vital liquor. By what impulſe it is moved, is ſomewhat hard to diſcover. It ſeems to be from the difference of day and night, and other changes in the heat of the air: for the heat dilating, and the cold contracting thoſe little tubes; ſuppoſing there be valves in them, it is eaſy to be conceived how the circulation is performed in plants, where it is

not required to be ſo rapid and quick as in animals.

NATURE has provided for the propagation of the ſpecies of plants ſeveral ways. The firſt and general is by ſeed. Beſides this, ſome plants are raiſed from any part of the root ſet in the ground: others by new roots, that are propagated from the old ones, as in tulips: others by off-ſets; and in others, the branches, ſet in the ground, will take root and grow: and laſt of all, grafting and inoculation, in certain ſorts, are known ways of propagation. All

theſe ways of encreaſing plants, make one good part of the ſkill of gardening; and from the books of gardeners may be beſt learnt.

CHAP. X.

OF ANIMALS.

THERE is another ſort of creatures belonging to this our earth, rather as inhabitants than parts of it. They differ in this from plants, that they are not fixed to any one place, but have a freedom of motion up and down, and beſides have ſenſe to guide them in their motions.

MAN, and brute, divide all the animals of this our globe.

BRUTES may be conſidered as either aerial, terreſtrial, aquatic, or amphibious. I call thoſe aerial, which have wings, wherewith they can ſupport themſelves in the air. Terreſtrial, are thoſe whoſe only place of reſt is upon the earth. Aquatic, are thoſe whoſe conſtant abode is upon the water. Thoſe are called amphibious, which live freely in the air upon the earth; and yet are obſerved to live long upon the water, as if they were natural inhabitants of that element: tho' it be worth the examination to know, whether any of thoſe creatures that

live at their eaſe, and by choice, a good while, or at any time upon the earth, can live a long time together perfectly under water.

AERIAL animals may be ſubdivided into birds, and flies.

FISHES, which are the chief part of aquatic animals, may be divided into ſhell-fiſhes, ſcaly-fiſhes, and thoſe that have neither apparent ſcales nor ſhells.

AND the terreſtrial animals may be divided into quadrupeds or beaſts, reptiles, which have

many feet, and ſerpents, which have no feet at all.

INSECTS, which, in their ſeveral changes, belong to ſeveral of the before mentioned diviſions, may be conſidered together as one great tribe of animals. They are called inſects, from a ſeparation in the middle of their bodies, whereby they are, as it were, cut into two parts, which are joined together by a ſmall ligature: as we ſee in waſps, common flies, and the like.

BESIDES all theſe, there are ſome animals that are not per-

fectly of theſe kinds, but placed, as it were, in the middle betwixt two of them, by ſomething of both; as bats, which have ſomething of beaſts, and birds in them.

SOME reptiles of the earth, and ſome of the aquatics, want one or more of the ſenſes, which are in perfecter animals; as worms, oyſters, cockles, *etc.*

ANIMALS are nouriſhed by food, taken in at the mouth, digeſted in the ſtomach, and thence, by fit veſſels, diſtributed over the whole body, as is deſcribed in books of anatomy.

THE greateſt part of animals have five ſenſes, viz. ſeeing, hearing, ſmelling, taſting, and feeling. Theſe, and the way of nouriſhment of animals, we ſhall more particularly conſider; becauſe they are common to man with beaſts.

THE way of nouriſhment of animals, particularly of man, is by food taken in at the mouth, which, being chewed there, is broken and mixed with the ſaliva, and thereby prepared for an eaſier and better digeſtion in the ſtomach.

WHEN the ſtomach has performed its office upon the food, it protrudes it into the guts, by whoſe periſtaltic motion it is gently conveyed along thro' the guts; and as it paſſes, the chyle, which is the nutritive part, is ſeparated from the excrementitious by the lacteal veins; and from thence conveyed into the blood, with which it circulates, till it ſelf be concocted into blood. The blood being by the *vena cava* brought into the right ventricle of the heart, by the contraction of that muſcle, is driven thro' the *arteria pulmonaris* into the lungs; where

the conſtantly-inſpired air mixing with it, enlivens it; and from thence being conveyed by the *vena pulmonaris* into the left ventricle of the heart, the contraction of the heart forces it out, and by the arteries diſtributes it into all parts of the body; from whence it returns by the veins into the right ventricle of the heart to take the ſame courſe again. This is called the circulation of the blood; by which life and heat are communicated to every part of the body.

In the circulation of the blood, a good part of it goes up into the

head, and by the brains are ſepa-rated from it, or made out of it, the animal ſpirits, which, by the nerves, impart ſenſe and motion to all parts of the body.

THE inſtruments of motion are the muſcles, the fibres whereof contracting themſelves, move the ſeveral parts of the body.

THIS contraction of the muſcles is in ſome of them by the direction of the mind, and in ſome of them without it; which is the difference between volun-tary, and involuntary motions, in the body.

CHAP. XI.

OF THE FIVE SENSES.

OF SEEING.

THE organ of ſeeing is the eye; conſiſting of variety of parts wonderfully contrived, for the admitting and refracting the rays of light; ſo that thoſe that come from the ſame point of the object, and fall upon different parts of the pupil, are brought to meet again at the bottom of the eye, whereby the whole object

is painted on the retina that is ſpread there.

THAT, which immediately affects the ſight, and produces in us that ſenſation, which we call ſeeing, is light.

LIGHT may be conſidered either, firſt, as it radiates from luminous bodies directly to our eyes; and thus we ſee luminous bodies themſelves, as the ſun, or a flame, *etc.* or, ſecondly, as it is reflected from other bodies; and thus we ſee a man, or a picture by the rays of light reflected from them to our eyes.

BODIES, in reſpect of light, may be divided into three ſorts: firſt, thoſe that emit rays of light, as the ſun and fixt ſtars; ſecondly, thoſe that tranſmit the rays of light, as the air; thirdly, thoſe that reflect the rays of light, as iron, earth, *etc.* the firſt are called luminous; the ſecond pellucid; and the third opaque.

THE rays of light themſelves are not ſeen: but by them, the bodies, from which they originally come; as the ſun, or a fixt ſtar: or the bodies, from which they are reflected; as a horſe, or

a tulip. When the moon ſhines, we do not ſee the rays which come from the ſun to the moon; but by them we ſee the moon from whence they are reflected.

IF the eye be placed in the medium through which the rays paſs to it, the medium is not ſeen at all: for inſtance, we do not ſee the air thro' which the rays come to our eyes. But if a pellucid body, thro' which the light comes, be at a diſtance from our eye, we ſee that body, as well as the bodies from whence the rays come, that paſs through them to come to our eyes. For inſtance, we do

not only ſee bodies thro' a pair of ſpectacles, but we ſee the glaſs itſelf. The reaſon whereof is, that pellucid bodies, being bodies, the ſurfaces of which reflect ſome rays of light from their ſolid parts; theſe ſurfaces, placed at a convenient diſtance from the eye, may be ſeen by thoſe reflected rays: as, at the ſame time, other bodies beyond thoſe pellucid ones may be ſeen by the tranſmitted rays.

OPAQUE bodies are of two ſorts, ſpecular, or not ſpecular. Specular bodies, or mirrors, are ſuch opaque bodies whoſe ſur-

faces are poliſhed; whereby they, reflecting the rays in the ſame order as they come from other bodies, ſhew us their images.

THE rays that are reflected from opaque bodies, always bring with them to the eye the idea of colour; and this colour is nothing elſe in the bodies, but a diſpoſition to reflect to the eye more copiouſly one ſort of rays, than another. For particular rays are originally endowed with particular colours: ſome are red, others blue, others yellow, and others green, *etc.*

EVERY ray of light, as it comes from the ſun, ſeems a bundle of all theſe ſeveral ſorts of rays: and as ſome of them are more refrangible than others; that is, are more turned out of their courſe, in paſſing from one medium to another; it follows, that after ſuch refraction they will be ſeparated, and their diſtinct colour obſerved. Of theſe, the moſt refrangible are violet, and the leaſt red; and the intermediate ones, in order, are indigo, blue, green, yellow, and orange. This ſeparation is very entertaining, and will be obſerved

with pleaſure in holding a priſm in the beams of the ſun.

As all theſe rays differ in refrangibility, ſo they do in reflexibility, that is, in the property of being more eaſily reflected from certain bodies, than from others: and hence ariſe, as hath been ſaid, all the colours of bodies, which are, in a manner, infinite, as an infinite number of compoſitions, and proportions of the original colours, may be imagined.

THE whiteneſs of the ſun's light is compounded of all the o-

riginal colours mixed in a due proportion.

WHITENESS, in bodies, is but a diſpoſition to reflect all colours of light, nearly in the proportion they are mixt in the original rays: as, on the contrary, blackneſs is only a diſpoſition to abſorb or ſtifle, without reflection, moſt of the rays of every ſort that fall on the bodies.

LIGHT is ſucceſſively propagated, with an almoſt inconceivable ſwiftneſs: for it comes from the ſun to this our earth in about ſeven or eight minutes of

time, which diſtance is about 70,000,000 Engliſh miles.

BESIDES colour, we are ſuppoſed to ſee figure; but in truth, that which we perceive when we ſee figure, as perceivable by ſight, is nothing but the termination of colour.

OF HEARING.

NEXT to ſeeing, hearing is the moſt extenſive of our ſenſes. The ear is the organ of hearing, whoſe curious ſtructure is to be learnt from anatomy.

THAT, which is conveyed into the brain by the ear, is called ſound: tho' in truth, till it come to reach and affect the perceptive part, it be nothing but motion.

THE motion, which produces in us the perception of ſound, is a vibration of the air, cauſed by

an exceeding ſhort, but quick, tremulous motion of the body, from which it is propagated; and therefore we conſider and denominate them as bodies ſounding.

THAT ſound is the effect of ſuch a ſhort, briſk, vibrating motion of bodies, from which it is propagated, may be known from what is obſerved and felt in the ſtrings of inſtruments, and the trembling of bells, as long as we perceive any ſound come from them; for as ſoon as that vibration is ſtopt, or ceaſes in them, the perception ceaſes alſo.

THE propagation of ſound is very quick, but not approaching that of light. Sounds move about eleven hundred and forty Engliſh feet, in a ſecond minute of time; and in ſeven or eight minutes of time, they move about one hundred Engliſh miles.

OF SMELLING.

SMELLING is another ſenſe, that ſeems to be wrought on by bodies at a diſtance; tho' that which immediately affects the organ, and produces in us the ſenſation of any ſmell, are effluvia's, or inviſible particles, that, coming from bodies at a diſtance, immediately affect the olfactory nerves.

SMELLING bodies ſeem perpetually to ſend forth effluvia's or ſteams, without ſenſibly waſting at all. Thus a grain of muſk

will ſend forth odoriferous particles for ſcores of years together, without its being ſpent: whereby one would conclude that theſe particles are very ſmall; and yet it is plain, that they are much groſſer than the rays of light, which have a free paſſage thro' glaſs; and groſſer alſo than the magnetic effluvia's, which paſs freely thro' all bodies, when thoſe, that produce ſmell, will not paſs the thin membranes of a bladder, and many of them ſcarce ordinary white paper.

THERE is a great variety of ſmells, tho' we have but a few

names for them: ſweet, ſtinking, ſower, rank, and muſty, are almoſt all the denominations we have for odours; tho' the ſmell of a violet, and of muſk, both called ſweet, are as diſtinct as any two ſmells whatſoever.

OF TASTE.

TASTE is the next ſenſe to be conſidered.

THE organ of taſte is the tongue and palate.

BODIES that emit light, ſounds, and ſmells, are ſeen, heard, and ſmelt at a diſtance: but bodies are not taſted, but by immediate application to the organ; for till our meat touch our tongues or palates, we taſte it not, how near ſoever it be.

IT may be obſerved of taſte, that though there be a great variety of them, yet, as in ſmells, they have only ſome few general names, as ſweet, bitter, ſower, harſh, rank, and ſome few o-thers.

OF TOUCH.

THE fifth and laſt of our ſenſes is touch; a ſenſe ſpread over the whole body, though it be moſt eminently placed in the ends of the fingers.

By this ſenſe the tangible qualities of bodies are diſcerned; as hard, ſoft, ſmooth, rough, dry, wet, clammy, and the like.

But the moſt conſiderable of the qualities, that are perceived by this ſenſe, are heat, and cold.

THE due temperament of thoſe two oppoſite qualities, is the great inſtrument of nature, that ſhe makes uſe of, in moſt, if not all, her productions.

HEAT is a very briſk agitation of the inſenſible parts of the object, which produces in us that ſenſation, from whence we denominate the object hot: ſo what in our ſenſation is heat, in the object is nothing but motion. This appears by the way whereby heat is produced, for we ſee that the rubbing of a braſs nail upon a board, will make it very hot; and

the axle-trees of carts or coaches are often hot, and ſometimes to a degree, that it ſets them on fire, by the rubbing of the wheel upon it.

On the other ſide, the utmoſt degree of cold is the ceſſation of that motion of the inſenſible particles, which to our touch is heat.

Bodies are denominated hot and cold in proportion to the preſent temperament of that part of our body, to which they are applied; ſo, that feels hot to one, which ſeems cold to another; nay, the ſame body felt by the two hands of the ſame man, may at the ſame time appear hot to

the one, and cold to the other; becauſe the motion of the inſenſible particles of it may be more briſk than that of the particles of the other.

BESIDES the objects beforementioned, which are peculiar to each of our ſenſes, as light, and colour of the ſight; ſound of hearing; odours of ſmelling; ſavours of taſting; and tangible qualities of the touch; there are two others that are common to all the ſenſes; and thoſe are pleaſure and pain, which they may receive by and with their peculiar objects. Thus too much light

offends the eye; ſome ſounds delight, and others grate the ear; heat in a certain degree is very pleaſant, which may be augmented to the greateſt torment: and ſo the reſt.

THESE five ſenſes are common to beaſts with men; nay in ſome of them, ſome brutes exceed mankind. But men are endowed with other faculties, which far excel any thing that is to be found in the other animals, in this our globe.

MEMORY alſo, brutes may be ſuppoſed to have, as well as men.

CHAP. XII.

OF THE UNDERSTANDING OF MAN.

THE underſtanding of man does ſo ſurpaſs that of brutes, that ſome are of opinion, brutes are mere machines, without any manner of perception at all. But letting this opinion alone, as ill grounded, we will proceed to the conſideration of human underſtanding, and the diſtinct operations thereof.

THE loweſt degree of it conſiſts

in perception, which we have before in part taken notice of, in our diſcourſe of the ſenſes. Concerning which it may be convenient farther to obſerve, that to conceive a right notion of perception, we muſt conſider the diſtinct objects of it, which are ſimple ideas; *v. g.* ſuch as are thoſe ſignified by theſe words, ſcarlet, blue, ſweet, bitter, heat, cold, *etc.* from the other objects of our ſenſes; to which we may add the internal operations of our own minds, as the objects of our own reflection, ſuch as are thinking, willing, *etc.*

OUT of theſe ſimple ideas are made, by putting them together, ſeveral compounded, or complex ideas; as thoſe ſignified by the word pebble, marygold, horſe.

THE next thing the underſtanding doth in its progreſs to knowlege, is to abſtract its ideas, by which abſtraction they are made general.

A GENERAL idea is an idea in the mind, conſidered there as ſeparated from time and place; and ſo capable to repreſent any particular being that is conform-

able to it. Knowlege, which is the higheſt degree of the ſpeculative faculties, conſiſts in the perception of the truth of affirmative, or negative propoſitions.

THIS perception is either immediate, or mediate. Immediate perception of the agreement or diſagreement of two ideas, is when, by comparing them together in our minds, we ſee, or, as it were, behold, their agreement or diſagreement. This therefore is called intuitive knowlege. Thus we ſee that red is not green; that the whole is big-

ger than a part; that two and two are equal to four.

THE truth of theſe, and the like propoſitions, we know by a bare ſimple intuition of the ideas themſelves, without any more ado: and ſuch propoſitions are called ſelf-evident.

THE mediate perception of the agreement or diſagreement of two ideas, is when, by the intervention of one or more other ideas, their agreement or diſagreement is ſhewn. This is called demonſtration, or rational knowlege. For inſtance, the in-

equality of the breadth of two windows, or two rivers, or any two bodies that cannot be put together, may be known by the intervention of the ſame meaſure, applied to them both; and ſo it it is in our general ideas, whoſe agreement or diſagreement may be often ſhewn by the intervention of ſome other ideas, ſo as to produce demonſtrative knowlege; where the ideas in queſtion cannot be brought together, and immediately compared, ſo as to produce intuitive knowlege.

THE underſtanding doth not know only certain truth; but al-

ſo judges of probability, which conſiſts in the likely agreement or diſagreement of ideas.

THE aſſenting to any propoſition as probable, is called opinion, or belief.

WE have hitherto conſidered the great and viſible parts of the univerſe, and thoſe great maſſes of matter, the ſtars, planets, and particularly this our earth, together with the inanimate parts, and animate inhabitants of it; it may be now fit to conſider what theſe ſenſible bodies are made of, and that is, of unconceivable ſmall bodies,

or atoms, out of whoſe various combinations bigger *molleculæ* are made; and ſo by a greater and greater compoſition bigger bodies; and out of theſe the whole material world is conſtituted.

By the figure, bulk, texture, and motion, of theſe ſmall and inſenſible corpuſcles, all the phænomena of bodies may be explained.

THE END.

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